



EDGEWOOD

RESEARCH, DEVELOPMENT & ENGINEERING CENTER

U.S. ARMY CHEMICAL AND BIOLOGICAL DEFENSE COMMAND

ERDEC-TR-243

**COGNITIVE PERFORMANCE DURING 10 HOURS
OF CONTINUOUS RESPIRATOR WEAR UNDER RESTING CONDITIONS**



David M. Caretti

RESEARCH AND TECHNOLOGY DIRECTORATE

March 1995

Approved for public release; distribution is unlimited.

19950531 062



Aberdeen Proving Ground, MD 21010-5423

Disclaimer

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorizing documents.

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE 1995 March		3. REPORT TYPE AND DATES COVERED Final, 94 Feb - 94 Apr
4. TITLE AND SUBTITLE Cognitive Performance During 10 Hours of Continuous Respirator Wear Under Resting Conditions			5. FUNDING NUMBERS PR-10162622A553	
6. AUTHOR(S) Caretti, David M.				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) DIR, ERDEC, ATTN: SCBRD-RTL, APG, MD 21010-5423			8. PERFORMING ORGANIZATION REPORT NUMBER ERDEC-TR-243	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) In order to assess the effects of long-term respirator wear on cognitive performance and signal detection, nine subjects continuously performed various computer controlled tasks under non-exercise conditions during two 10 hr days one with and one without (control) wearing a respirator. Cognitive tasks assessed speed of information processing, language skills, rapid visual scanning, recognition memory, and divided attention. Subject anxiety levels were also assessed. Cognitive performance did not differ significantly between respirator and control trials and was not changed over time. In general, mean decision-making times were slower during respirator wear compared to control, but the differences were not significant. Mask wear significantly increased signal detection time for stimuli located peripherally at 38°, 64°, and 90° from center and for stimuli located above and below the horizontal axis of view. However, time had no effect on signal detection. Mean anxiety levels were slightly higher during mask wear trials compared to control at each measurement period, but no significant effects of mask wear were observed. The implications of these findings for military performance suggest that continuous mask wear over a 10 hr period in the absence of physical stress should not inhibit soldier cognitive function or signal detection capability.				
14. SUBJECT TERMS Anxiety Signal detection Respirator Cognitive performance Reaction time			15. NUMBER OF PAGES 27	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UL	

Blank

PREFACE

The work described in this report was authorized under Project No. 10162622A553, CB Defense/General Investigation. This work was started in February 1994 and completed in April 1994.

In conducting the research described in this report, the investigators adhered to Army Regulation 70-25, Research and Development--Use of Volunteers as Subjects of Research, dated 25 January 1991, as promulgated by the Office of The Surgeon General, Department of the Army. Approval for the use of human volunteers was granted by the U.S. Army Edgewood Research, Development and Engineering Center Human Use Committee, Protocol Log No. 9315S.

The use of trade names or manufacturers' names in this report does not constitute an official endorsement of any commercial products. This report may not be cited for purposes of advertisement.

This report has been approved for release to the public. Registered users should request additional copies from the Defense Technical Information Center; unregistered users should direct such requests to the National Technical Information Service.

Acknowledgments

Acknowledgements for invaluable assistance in conducting the study are extended to: SGT Leslie A. Bay-Hansen, Respiratory Protection Technology Team, SCBRD-RTL, for all aspects of test administration and data analysis; Dr. Wade D. Kuhlmann, Respiratory Protection Technology Team, SCBRD-RTL, for management support, data collection assistance, and observation of test volunteers; and Paul D. Gardner, Respiratory Protection Technology Team, SCBRD-RTL, for assistance with data collection and observation of test volunteers.

Accession For	
NTIS GRA&I	<input checked="checked" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

Blank

CONTENTS

1.	INTRODUCTION	7
2.	MATERIALS AND METHODS	8
2.1	Test Subjects	8
2.2	Experimental Procedures	8
2.2.1	Pre-test	8
2.2.2	Zero Hour	10
2.2.3	One Hour	14
3.	RESULTS	14
4.	DISCUSSION	22
5.	CONCLUSION	24
	LITERATURE CITED	25

FIGURES

1.	Schematic Representation of the Data Collection Procedures Over the 10 hour Test Period	9
2.	Diagram of the Perimeter Used to Assess Signal Detection	11
3.	Mean State-Anxiety (\pm S.D.) for Control and Mask Wear Conditions Over Time	15
4.	Mean Decision Making Speeds (DMS) for Each Choice Reaction Time Task for Each Measurement Period During Control and Mask Wear Trials	18
5.	Mean Detection Time at Each Peripheral Stimulus Location for Control and Mask Conditions	20
6.	Mean Detection Time for Each Test Condition for the Four Stimuli on Each of the Eight Field Axis Positions	21

TABLES

I.	Mean Reaction Times (\pm S.D.) of Male and Female Subjects for Each CALCAP Task	17
II.	Mean Decision Making Speeds (\pm S.D.) of Male and Female Subjects for Each CALCAP Task	17
III.	Group Mean Mask Decision Making Speed Performance Ratings (\pm S.D.) for Each CALCAP Choice Reaction Time Task	19

COGNITIVE PERFORMANCE DURING 10 HOURS OF CONTINUOUS RESPIRATOR WEAR UNDER RESTING CONDITIONS

1. INTRODUCTION

The dangers present in the chemical battlefield result from several factors including the toxic effects of the agents, the stress effects of warfare itself, and the physiological and psychological (both perception and cognition) effects of wearing protective gear. Cognitive performance can also be affected by other stress reactions such as feelings of fear and anxiety. Research directed toward an understanding of the effects of protective ensembles on psychological performance describe anecdotal emotional impairments and infer some perceptual and cognitive effects (1,6,8,11,22). Also, the experimental conditions of these previous studies were such that full protective ensembles (mask and hood, overgarments, boots, and gloves) were worn by subjects at varying levels of physical exertion. The factor of full ensemble wear limits our ability to know whether the reported alterations in psychological performance resulted mainly from mask wear or if mask and overgarment wear equally influenced performance. Additionally, the different levels of exertion restrict the applicability of previous research findings to assessment of mask wear because the psychological effects of mask wear are considered to be more pronounced at low work rates due to a wearer's increased awareness of the mask (9).

Two particular investigations that truly assessed the effects of respirator wear on psychological and cognitive performance in the absence of other stressors (i.e. ensemble wear and exercise) had similar results. During three and a half hours of continuous mask wear Caretti *et al.* (4) found no significant differences in cognitive performance, measured by reaction time and response accuracy, during mask wear compared to the no mask condition. Wetherell (25) studied the effects of six hours of respirator wear on cognitive performance and observed no effect of mask wear on cognitive function. The inability to detect significant effects of mask wear on cognitive performance in these two studies does not prove that they do not exist but suggests that such short-term mask wear during very low levels of exertion may not provide adequate time to elicit changes in cognition. In fact, Wetherell (25) concluded that studies of longer duration should be carried out to allow possible fatigue effects to develop and should include measurements of signal detection.

With respect to the duration of mask wear for assessment of psychological and cognitive performance it becomes apparent that such studies need to be designed to reflect the anticipated wear time of masks in any chemically contaminated battlefield. Currently, it is estimated that continuous mask wear may be required for a minimum of 8 to 12 hours. Combining this information with that obtained from the studies of

Caretti *et al.* (4) and Wetherell (25) it is evident that significant shortcomings exist in our knowledge of the effects of mask wear on cognitive performance as they relate to practical use. Therefore, this study was designed to evaluate the effects of long-term mask wear alone on cognitive performance and signal detection in the absence of the stressors of ensemble wear and exercise.

2. MATERIALS AND METHODS

2.1 Test Subjects

Nine subjects (6 males and 3 females) with the mean age of 27 ± 5 years (mean \pm S.D.) volunteered for this study. Male and female sub-groups averaged 27 ± 6 and 29 ± 2 years of age, respectively. To be considered for inclusion in the study, individuals were to demonstrate a static visual acuity of 20/40 or better without corrective lenses to eliminate any possible effects of visual acuity on test results. Volunteers were thoroughly briefed on the nature and purpose of the study and were accepted for participation after giving their free and informed consent.

2.2 Experimental Procedures

All experimental procedures were conducted at room temperature (20-24°C). Subjects were directed to get adequate rest the night before each test, to eat breakfast, and to drink plenty of fluids, excluding alcohol and caffeine, before reporting to the laboratory. Two random test iterations, one 10 hour test without a mask (control) and the other during 10 hours of continuous wear of the U.S. Army M40 respirator, were executed on two separate, non-consecutive days. Data collection procedures for the two test iterations were analogous. Figure 1 presents a schematic illustration of data collection procedures over time.

2.2.1 Pre-test

Before cognitive performance and signal detection testing commenced, subjects completed the State-Trait Anxiety inventories (STAI) (24). The Trait-Anxiety Inventory evaluated how respondents felt in general. This questionnaire was administered to each subject only at the beginning of the initial test iteration. The State Anxiety-Inventory consisted of 20 statements that appraised how subjects felt at a particular moment. Each subject completed the State Anxiety questionnaire before each test iteration.

Signal detection testing of the overall binocular visual field was then assessed with a perimeter and computer system developed specifically for this purpose (15). The stimulus configuration of this perimeter consisted of a hemispheric array of 32 units of light emitting diodes (LEDs) arrayed along eight radial axes dispersed about

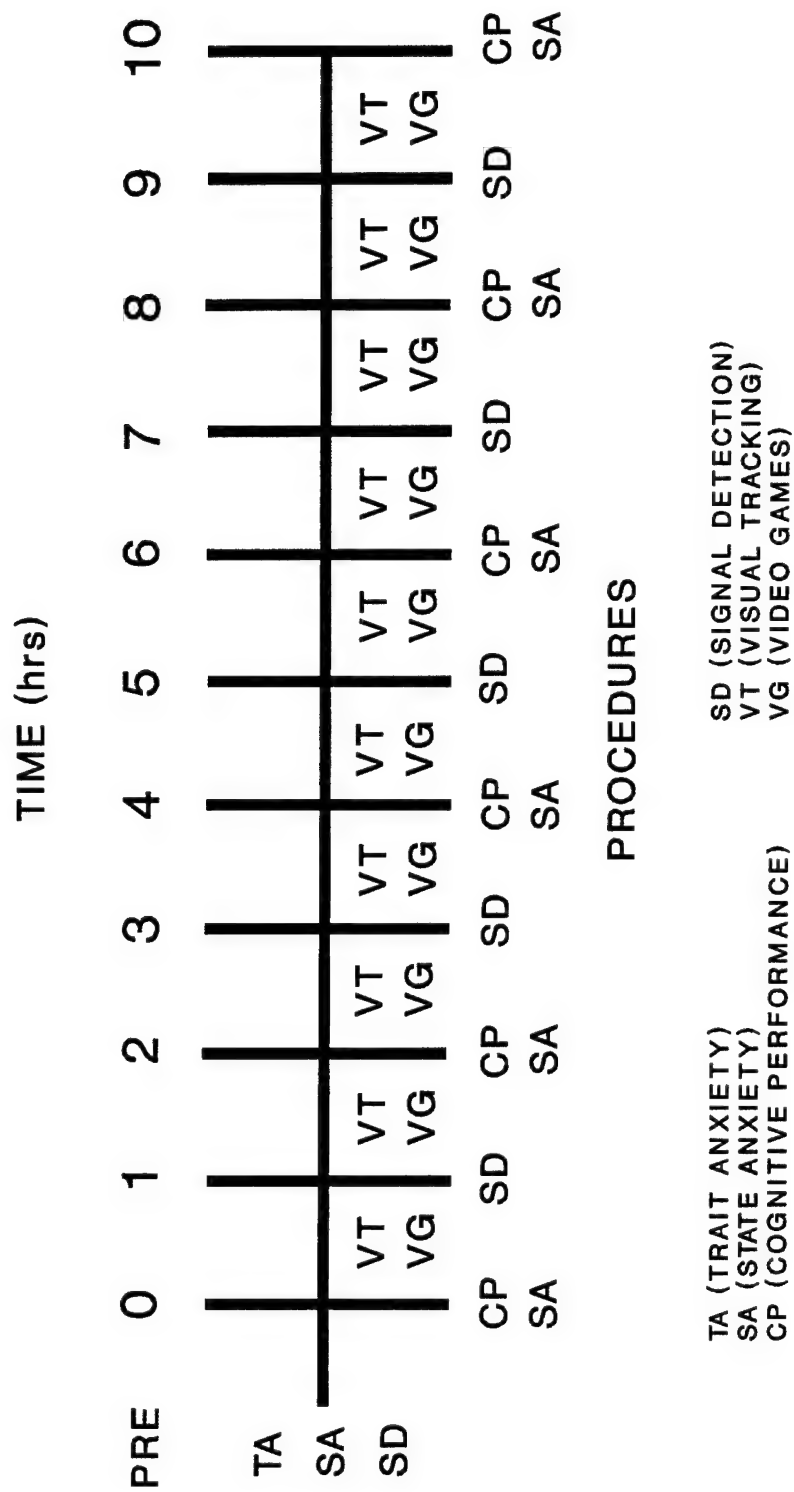


Fig.1. Schematic representation of the data collection procedures over the 10 hour test period.

the subject's central line of sight. The eight curved ribs of the structure were spaced at 45° intervals to form a 81.28 cm diameter hemisphere. The LEDs were positioned on each of the eight ribs at 12°, 38°, 64° and 90° angular displacement from the center of the hemisphere (Fig. 2). The common radius of the hemispheric rib structure (40.64 cm) set all the stimulus lights at the same distance from the viewing position, and thus subtended the same visual angle. All metal surfaces of the rib structure were painted flat black and the back side of the entire assembly was enclosed in a matte black fabric cover.

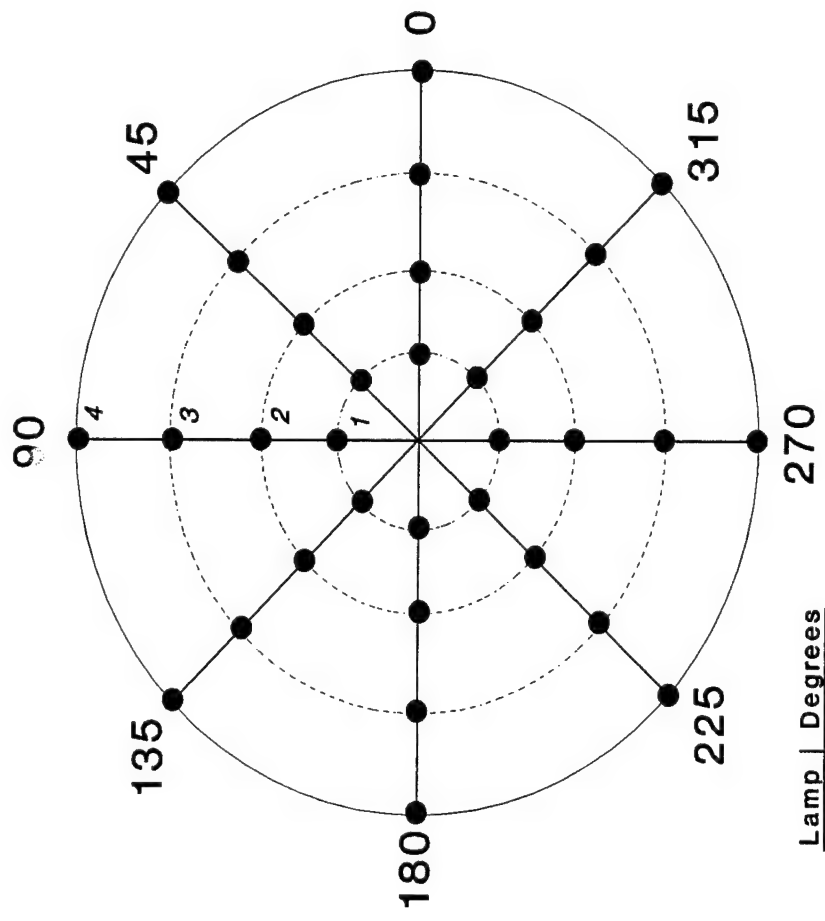
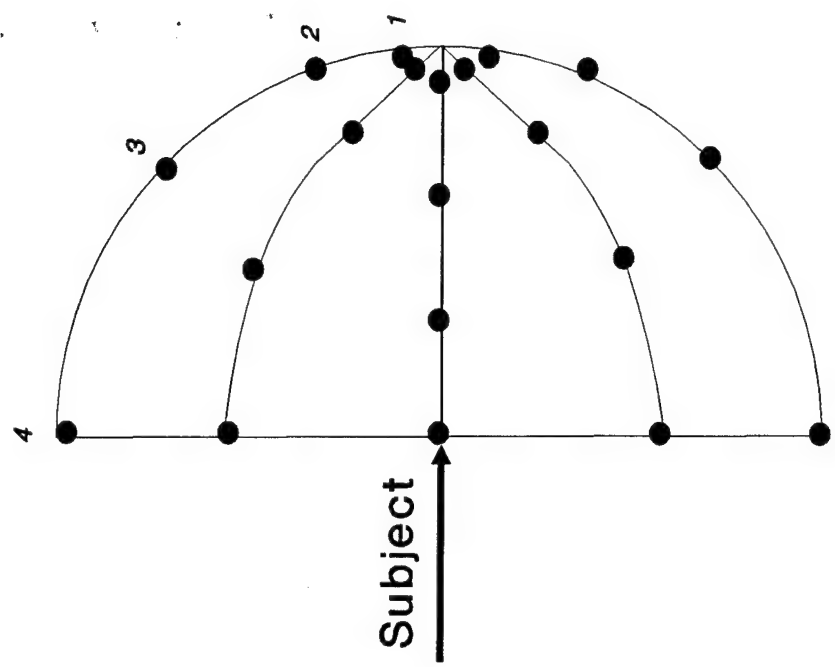
Subjects were seated in a contoured seat with an adjustable headrest. The seat was positioned so that the subject's line of sight intersected the center of the hemisphere and the edge of the hemisphere abutted the peripheral limit of the visual field at 90°. Subject head movements were partially restrained by both the seat headrest and a foam pillow placed between the back of the subject's head and the headrest. Even so, subjects were directed to avoid moving their heads as much as possible.

Subjects were instructed to view the display continuously while fixing their sight on its center, and to depress a hand-held button whenever the onset of a signal light was detected. In each test run, subjects received all 32 stimulus lights presented in random order. A Hewlett-Packard 9236 Computer controlled signal presentation and recorded each subject's response times. The time intervals between occurrences of stimuli were randomized at 5 to 25 seconds so that subjects could not anticipate the time of onset or location of any stimulus. An undetected stimulus was considered to be missed after 5 s and was given a response time score of that value.

2.2.2 Zero Hour

Cognitive performance was assessed using the California Computerized Assessment Package (CALCAP®; Norland Software). The CALCAP is a computerized assessment technique that measures reaction time and speed of information processing. The CALCAP test battery has been used to study changes in reaction time and speed of information processing in many clinical perturbations (19). Findings to date suggest that the CALCAP is a practical and inexpensive tool for detecting cognitive decline, and may be more sensitive than conventional neuropsychological procedures for detecting cognitive changes over time (19).

The CALCAP test battery incorporates a series of ten simple and choice reaction time measures administered by computer and provides a measure of sustained attention and reaction time. The tasks are self-explanatory and need only minimal supervision by the investigator. The individual reaction time measures are designed to assess various cognitive domains including reaction time (speed of processing), language skills, rapid visual scanning, form discrimination, recognition memory, and divided attention. In addition, measurements of response accuracy, or true and false



Lamp	Degrees
1	12
2	38
3	64
4	90

Fig. 2. Diagram of the perimeter used to assess signal detection.

positive responses, are obtained for each cognitive task.

To perform the tasks of the CALCAP test battery, subjects were seated before a computer (an AT&T model XP1076 or Compaq Deskpro 386S model 2530 with an 80386 microprocessor running at 16 MHz, and a VGA color monitor). Subjects were instructed to focus on the computer monitor and respond only to specific visual stimuli by depressing the space-bar of the computer keyboard using their dominant hand. The stimulus materials, which have been described in detail elsewhere (4,19), were presented in the following manner:

1. Simple reaction time - Dominant hand (SRT-D). Subjects pressed the space-bar with their dominant hand as soon as they saw anything at all on the monitor. This procedure provided a basal measure of reaction time. This task was repeated in the middle (after 10 minutes (SRT-D2)) and at the end (after 20-25 minutes (SRT-D3)) of the computerized procedures to assess fatigue effects.
2. Simple reaction time - Non-dominant hand (SRT-ND). Same as the previous task except the non-dominant hand was used. This task was only presented once in the test battery.
3. Choice reaction time for single digits (CRT). Subjects responded to seeing the number 7 and did nothing when other numbers were observed. This task added a simple element of memory.
4. Serial pattern matching (SPM). Subjects responded when two of the same number were observed in sequence. This procedure incorporated a more complex element of memory scanning and divided attention.
5. Lexical discrimination (LD). Subjects reacted when seeing a word which fit into the specific category of animal names, but not when a word which fit into a category of non-animals was observed. This task required rapid language processing.
6. Visual selective attention (VSA). Subjects responded when they saw the specific word "SEVEN" in the center of the screen while an additional set of words was being displayed around the periphery of the target stimulus in the center of the screen. The ability to focus attention was assessed using this task.
7. Response reversal and rapid visual scanning (RVS). This task was identical to task 6, but the subject had to ignore the stimuli presented in the center of the screen while responding to stimuli around the periphery of the computer screen. This assignment tested a subject's ability to change cognitive set from the previous task and required more rapid visual scanning.
8. Form discrimination (FD). Subjects were shown three geometric figures simultaneously and asked to press a key only when two of the figures were identical. This task required rapid comparison of non-nameable forms and tested iconic memory of the figures.

To familiarize the subject with the computerized procedures, the CALCAP program presented practice trials to the user before proceeding to each individual task. For the simple reaction time measures, the CALCAP program calculated mean reaction time by ignoring the best and worst response times and then averaging the

remaining responses. For the choice reaction time procedures, mean reaction time was determined by dropping the two best and worst measures and then averaging the remaining responses. Correct responses to target stimuli were classified as true positive reactions. Responses to nontarget stimuli were recorded as false positive reactions.

Since it has been suggested that decision-making speed (choice reaction time minus simple reaction time) may be a better measure than choice reaction time alone for assessing changes in speed of cognitive processing (4,19), differences in decision-making time between control and respirator trials were evaluated for each subject. Decision-making time was determined by subtracting the average of the three dominant-hand simple reaction time tasks from each choice reaction time measure.

When performing the CALCAP procedures during the respirator trial, simultaneous breath-by-breath measurements of fractional carbon dioxide (CO_2) concentration within the respirator nose cup and inspired volume were obtained to determine mask effective dead space. Fractional carbon dioxide concentration was measured with a mass spectrometer (Perkin-Elmer, MGA model 1100). Inspiratory volume was obtained with a turbine flowmeter (K.L. Engineering K-520 transducer with a KTC-3-D compensator). This data was collected to determine whether large amounts of CO_2 were being inspired during respirator wear. Also, since hypercapnic breathing has been shown to increase anxiety levels of CO_2 sensitive individuals (23) and an increase in anxiety may adversely affect cognitive performance, the hypothesis that decrements in cognition could be related to respirator dead space was tested. Calculation of effective dead space was performed according to the methods of Caretti *et al.* (3)

Following completion of the CALCAP test battery, subjects again completed the State-Anxiety questionnaire. Subjects then performed a computerized saccadics (visual tracking) exercise (Vision Aerobics®). For this exercise, the display screen was divided into a regular matrix of 16 x 29 squares and in each square location a letter "A" or "L" would appear one at a time in random order and location. Subjects watched the computer monitor for a letter to flash and then responded to seeing the letter by pressing the keyboard key that matched the letter that was shown. A correct response had to be made within 0.67 s and only the first response was accepted. Once a response was made, another letter was presented. Subjects accumulate points for correct responses. In this exercise, accuracy was more meaningful than reaction time. The programmed level of difficulty for the computerized visual tracking task was uniform for all subjects. The complete exercise endured for approximately 10 minutes.

Each of these procedures were duplicated during hours 2, 4, 6, 8, and 10 of data collection. When not performing the tasks of the CALCAP test battery and the saccadics test, subjects were required to play video games at their own pace and skill

level. This time was also reserved for subjects to drink and to use the bathroom as needed. At no time was food consumption permitted. During the respirator trials, subjects obtained water through the respirator's drinking system.

2.2.3 One Hour

Subjects repeated the signal detection task followed by the visual tracking exercise. For the remainder of the hour subjects were again required to play video games at their own pace and skill level. These procedures were duplicated during hours 3, 5, 7, and 9 of testing.

3. RESULTS

Trait-Anxiety was relatively low for the subject group as a whole (29.7 ± 6.8) and ranged from 22 to 43. Male and female sub-groups reported comparable Trait-Anxiety levels (32.0 ± 7.1 vs. 25.0 ± 2.6). These Trait-Anxiety scores represent "low-anxious" individuals with relatively stable individual differences in anxiety proneness (24).

A three-way ANOVA (gender x mask condition x time) for State-Anxiety yielded an overall F of 30.7 ($df=1, 97$; $p<0.0001$) for mean State-Anxiety for the factor of gender, indicating a significant difference between male and female sub-groups independent of mask condition and time. Also, an overall F of 3.6 ($df=6, 97$; $p<0.005$) for the time factor was found, signifying a significant variation in State-Anxiety over time. Comparison of mean State-Anxiety scores for each measurement period revealed a significant increase in State-Anxiety during hours 8 and 10 compared to pre-test scores independent of gender and mask condition. Mean State-Anxiety was greater during respirator trials compared to control at each time period, but no significant effects of mask condition were found (Fig. 3).

For the saccadics exercise, the results were analyzed with respect to percent performance rating. Percent performance rating was calculated using the following equation:

$$\text{Performance Rating} = \frac{\text{Mask results}}{\text{Control results}} \times 100$$

Therefore, a mask performance rating represents a percent of the control (no mask) condition. A two-way ANOVA (gender x time) was utilized to assess mask performance ratings for the saccadics tests. No significant effects of gender or time were observed and an overall F of 0.28 ($df=10, 77$; $p=0.98$) for mean percent performance rating indicated there was no significant interaction of gender or time of

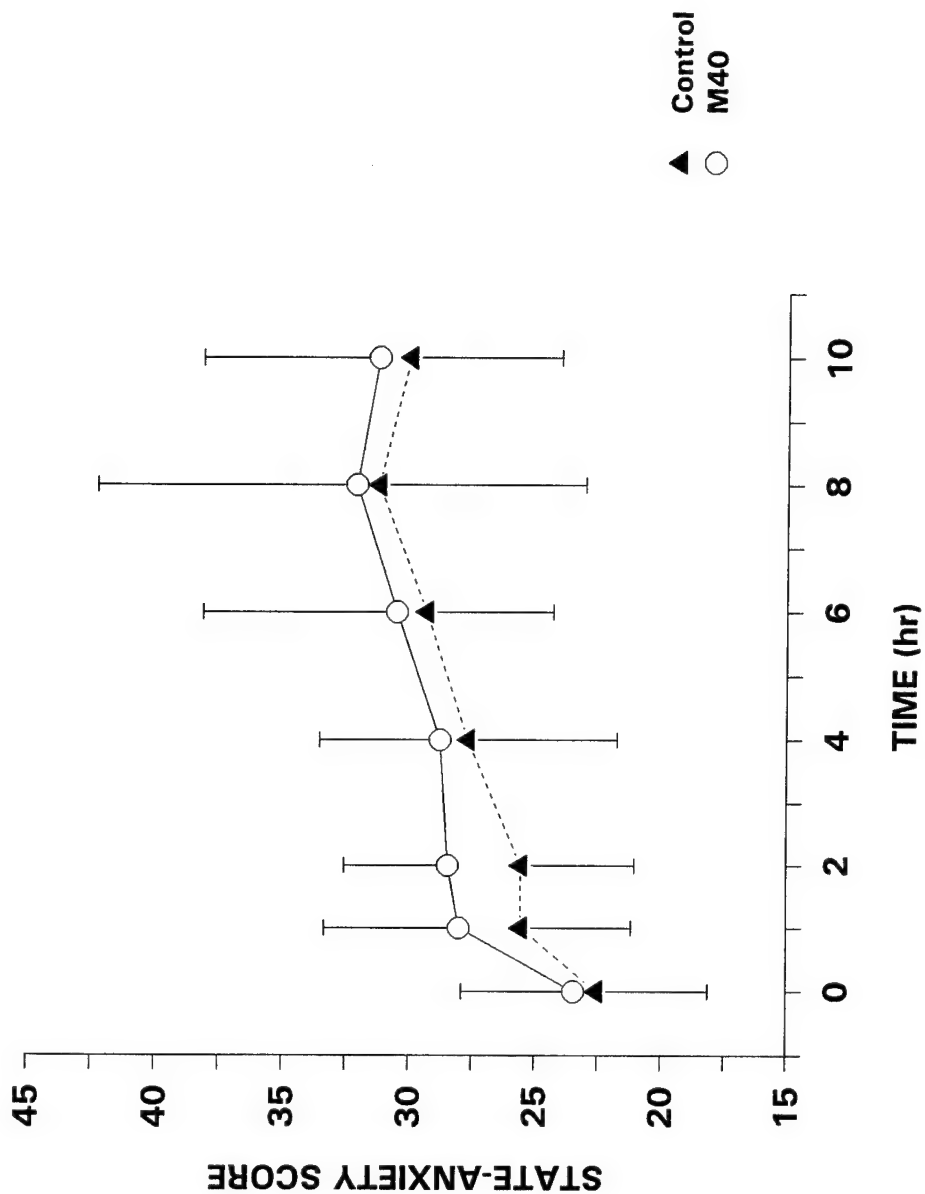


Fig. 3. Mean State-Anxiety (\pm S.D.) for control and mask wear conditions over time. No significant differences were observed between test conditions at each time of measurement.

measurement. Therefore, mask wear did not alter performance for the saccadics exercise at any time during testing.

Multivariate analysis of variance (MANOVA) of the CALCAP data was performed to ascertain whether cognitive performance (measured as reaction time) was influenced by gender, mask condition, or time over the 10 hour test period. A significant ($p < 0.0005$) overall gender effect for mean reaction time was established, but no significant interactions of mask condition or time of measurement were observed. Specifically, mean reaction time for female subjects was significantly faster compared to males for the SRT-ND task and the choice reaction time tasks of CRT, SPM, LD, VSA, and FD (Table I). Female subjects also demonstrated significantly faster decision making speed (DMS) than males for the choice reaction time tasks of CRT, SPM, LD, and FD (Table II). Again, no significant interactions of mask condition or time of measurement were observed. In general, decision making speed for the choice reaction time tasks appeared to be degraded most during mask wear in the sixth hour of testing (Fig. 4). However, after six hours of mask wear, decision making speeds were comparable or better than initial measurements (hour zero). Decision making speeds for all choice reaction time tasks were comparable for control and mask wear conditions for each hour of testing.

Mask performance ratings were also calculated for reaction time and decision making speed for the CALCAP tasks. For these variables, lower absolute results indicate improved performance. If mask wear resulted in better performance, performance ratings as calculated above would suggest that mask wear caused decreased performance compared to control. Thus, the equation was adjusted so that improvements during mask wear are expressed as performance ratings greater than 100%.

Results of a separate two-way MANOVA displayed no significant effects of gender or time of measurement on mask performance ratings for decision making speed. Because of the inequality among the variances for mean percent performance rating for each time period, the data were analyzed using non-parametric ANOVA. Decision making speed performance decrements for the subject group as a whole were greatest for all choice reaction time tasks except the SPM task during hour six of mask wear (Table III). However, no significant differences were found between measurement periods.

Response accuracy, measured as the percentage of true positive (errors of omission) and false positive responses (errors of commission) to each of the CALCAP choice reaction time procedures, did not differ within or between gender, mask condition, or time of measurement. No significant changes in mask effective dead space occurred over the 10 hour mask wear test period.

TABLE I. Mean Reaction Times (\pm S.D.) of Male and Female Subjects for Each CALCAP Task.

CALCAP Task	REACTION TIME (ms)	
	Males	Females
SRT-D1	309.2 \pm 46.5	293.0 \pm 20.8
SRT-ND	305.8 \pm 40.3	286.0 \pm 24.8 ¹
CRT	430.2 \pm 34.3	405.5 \pm 23.5 ¹
SPM	513.2 \pm 78.0	441.6 \pm 49.6 ¹
LD	495.2 \pm 45.5	461.1 \pm 20.7 ¹
SRT-D2	312.8 \pm 44.9	310.4 \pm 27.5
VSA	482.8 \pm 50.6	459.8 \pm 31.2 ¹
RVS	557.4 \pm 74.1	543.1 \pm 54.8
FD	640.5 \pm 120.2	576.8 \pm 28.2 ¹
SRT-D3	327.2 \pm 54.2	322.0 \pm 30.0

¹ Significant difference compared to males.TABLE II. Mean Decision Making Speeds (\pm S.D.) of Male and Female Subjects for Each CALCAP Task.

CALCAP Task	DECISION MAKING SPEED (ms)	
	Males	Females
CRT	113.8 \pm 38.2	97.1 \pm 27.4 ¹
SPM	196.8 \pm 66.4	133.2 \pm 46.1 ¹
LD	178.8 \pm 43.3	152.6 \pm 22.6 ¹
VSA	166.4 \pm 49.6	151.3 \pm 26.4
RVS	241.0 \pm 69.0	234.6 \pm 46.1
FD	324.1 \pm 105.8	268.4 \pm 24.2 ¹

¹ Significant difference compared to males.

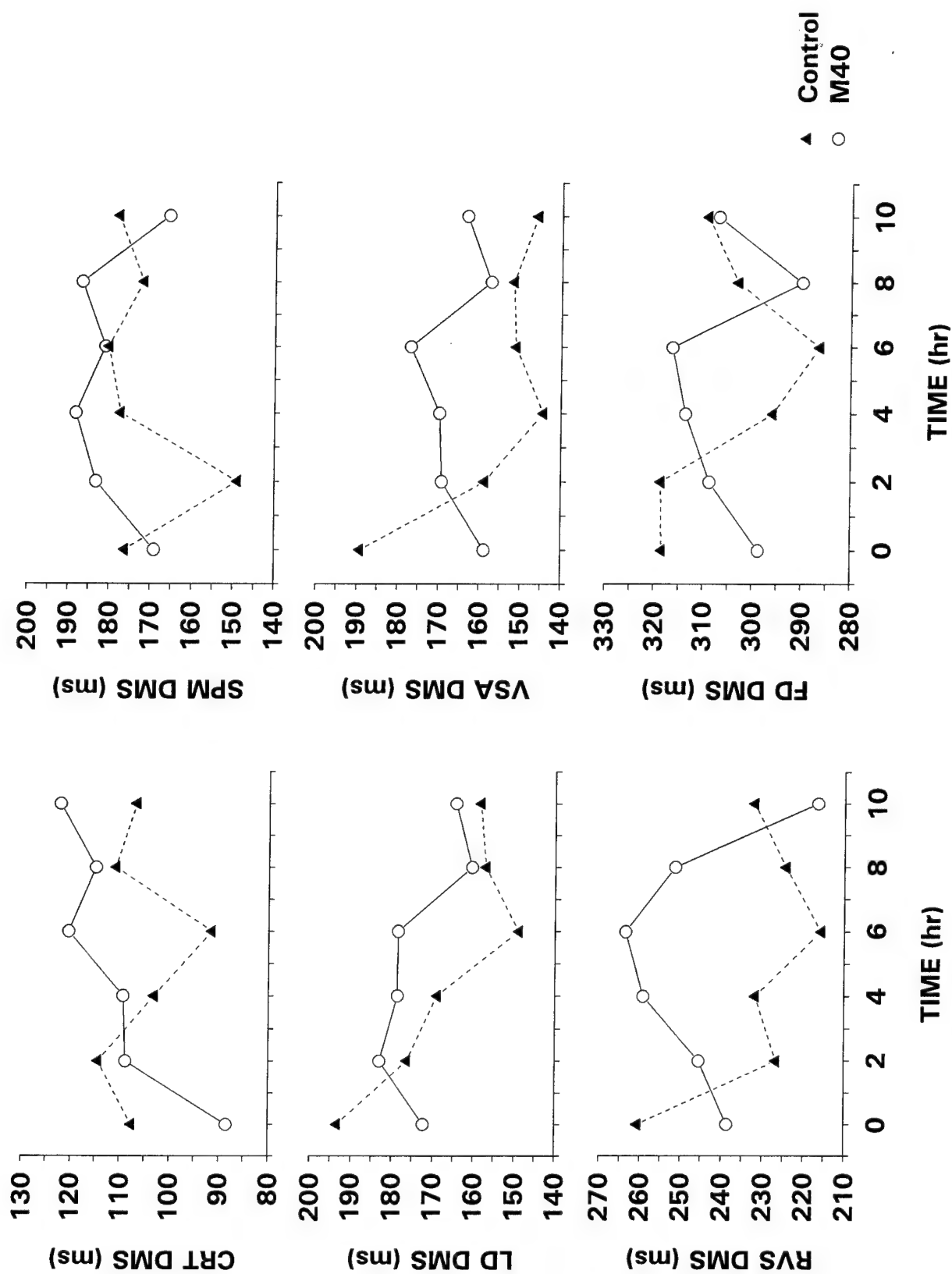


Fig. 4. Mean decision making speeds (DMS) for each choice reaction time task for each measurement period during control and mask wear trials. No significant differences were found between conditions for each task. CRT = choice reaction time, SPM = serial pattern matching, LD = lexical discrimination, VSA = visual selective attention, RVS = rapid visual scanning, and FD = form discrimination.

TABLE III. Group Mean Mask Decision Making Speed Performance Ratings (\pm S.D.) for Each CALCAP Choice Reaction Time Task.

DECISION MAKING SPEED PERFORMANCE RATING (%)						
Hour	CRT	SPM	LD	VSA	RVS	FD
0	118 \pm 35	98 \pm 42	110 \pm 9	109 \pm 34	105 \pm 26	104 \pm 17
2	101 \pm 35	64 \pm 50	94 \pm 26	89 \pm 26	89 \pm 24	99 \pm 26
4	85 \pm 48	91 \pm 19	91 \pm 22	77 \pm 25	85 \pm 20	90 \pm 36
6	66 \pm 38	97 \pm 32	72 \pm 42	76 \pm 41	77 \pm 38	87 \pm 37
8	88 \pm 37	80 \pm 42	92 \pm 37	82 \pm 43	80 \pm 31	103 \pm 15
10	84 \pm 45	117 \pm 25	100 \pm 16	90 \pm 29	106 \pm 14	101 \pm 13

A five-way ANOVA (gender x mask condition x time of measurement x rib field axis position x stimulus light location) produced significant overall effects for all factors except time of measurement for signal detection time. Overall, males exhibited a significantly faster signal detection time compared to females. The mean detection times for the interaction of gender and mask condition showed significant increases in time during mask wear compared to control for both gender groups. Independent of stimulus location, males demonstrated significantly faster detection times than females during control sessions, but times were identical for gender groups during mask wear.

Group mean detection times for each peripheral ring of stimuli (12°, 38°, 64° and 90°) are shown in Figure 5 for the control and M40 test conditions. The means for the rings reflect the effect of peripheralization of the stimulus (14). Mean detection time increased with greater peripheralization of the stimuli within each experimental condition. Impairments were significantly greater for the M40 mask wear condition compared to the no mask trial at stimulus locations of 38°, 64° and 90°.

Overall group mean detection times for the control and mask wear test conditions for the four stimuli on each of the eight axes are presented in Figure 6. The means for the axes indicate the effect of the stimulus' general location in the overall visual field (14). Compared to the no mask condition, detection time during mask wear was significantly greater at all field axis positions excluding 0° and 180°.

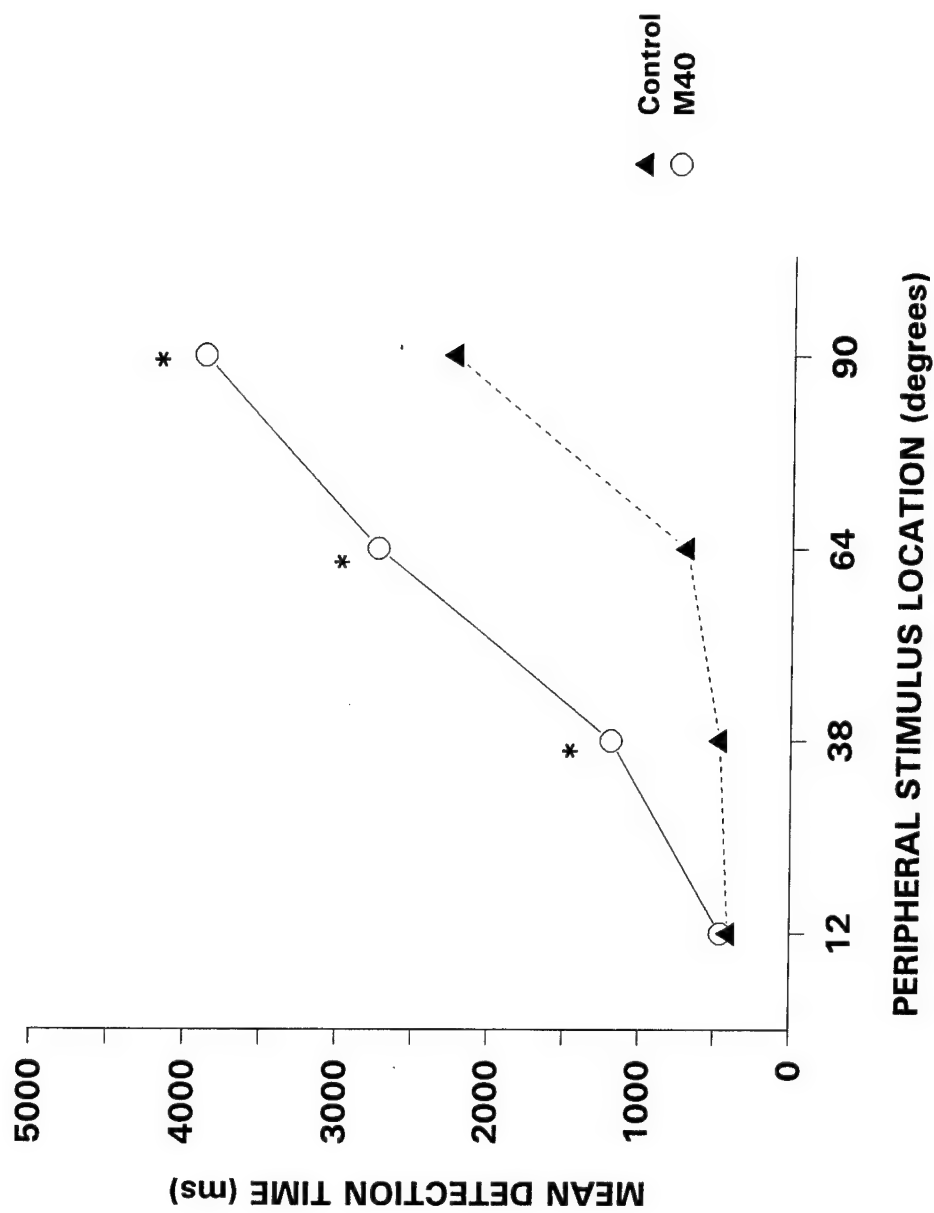


Fig. 5. Mean detection time at each peripheral stimulus location for control and mask conditions. Asterisk (*) indicates a significant difference between test conditions.

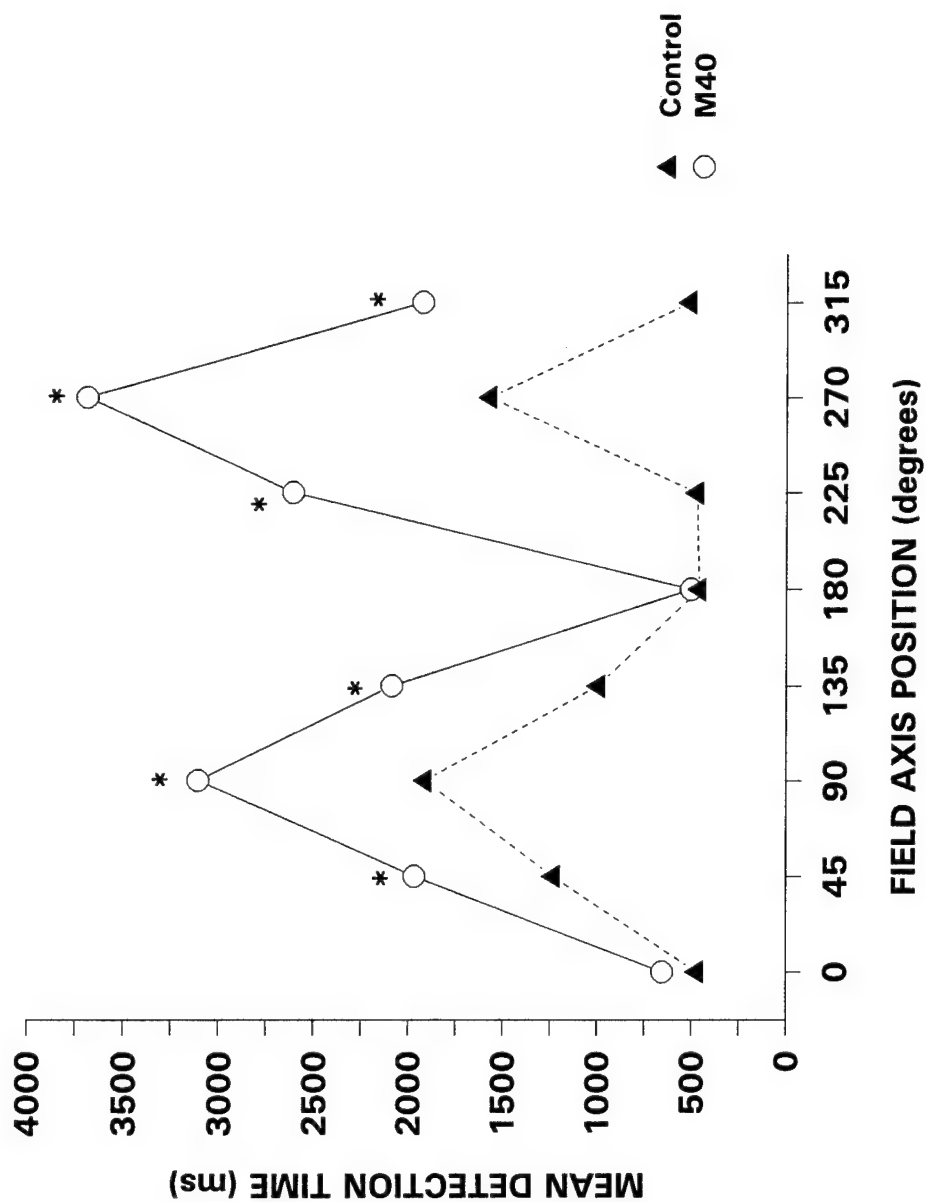


Fig. 6. Mean detection time for each test condition for the four stimuli on each of the eight field axis positions. Asterisk (*) represents a significant difference between the control and mask wear conditions.

4. DISCUSSION

Unimpaired soldier information processing and decision making is essential for successful combat mission performance. The limited data on the effects of protective ensemble wear on cognitive performance suggests that psychomotor performance and the commission of errors may be significantly impaired (7,8,14,21). However, cognitive performance has been found to be unaltered during respirator wear in the absence of other stressors over 3.5 and six hour time periods (4,25). In fact, some improvement in cognition has been reported as a result of respirator wear (4). The results of this 10 hour continuous mask wear investigation show that cognitive performance, as measured by simple and choice reaction time, was maintained during wear of the M40 respirator for the duration of testing. These results corroborate the findings of others who have reported that respirators have no significant effect on cognitive performance (4,25,26).

There is no concrete evidence to suggest that wearing respiratory protective devices would degrade cognitive performance, but it is believed that decreases in sensory input associated with respirator wear could impair cognition (1). In a previous investigation, Kelly *et al.* (10) reported detrimental effects of mask wear alone on cognitive performance. These investigators found mean simple reaction time to be significantly slower during four hours of mask wear compared to control conditions and simple reaction time showed a significant linear increase over time. These findings were attributed to subject fatigue or boredom. Comparable results were observed in an investigation of 4 hours of continuous MOPP IV (mask, gloves, boots, and protective overgarment) wear (11). Even though the simple reaction time task employed by Kelly *et al.* (10,11) appears to be identical to the same task in the CALCAP test battery, no significant effects of respirator wear or time of measurement were found for simple reaction measures in the current study.

An explanation for the general decrements observed for decision-making time up to six hours of continuous mask wear followed by a return of decision making speeds to initial values (Fig. 4) is not readily apparent. It is possible that subject fatigue or boredom peaked while wearing the mask during the six hour measurement period. In support of this, mask performance ratings for decision making speed for all tasks except serial pattern matching were most degraded at this point in time. In contrast, average decision making speeds for most choice reaction time tasks were quickest at this point in time for the control condition.

The only consistent finding related to decision making speed over time was that for all choice reaction time procedures mask wear resulted in faster responses for the first iteration (hour zero) of the CALCAP test battery. Increased arousal caused by the stress of the respirator could have initially improved subject attention, resulting in better concentration while performing the tasks of the CALCAP test battery. In addition, narrowing of the visual field and nearer focus of sight have been reported to

be associated with many stressors (16). It is possible that the reduced visual field of the respirator served to improve subject visual attention to the tasks by "filtering" peripheral distractions, thus allowing for better concentration during the first period of cognitive performance testing. An interaction of perceptual narrowing and increased arousal during respirator wear most likely propagated our findings. In general, the comparable decision making times found during mask wear for hours zero and ten may reflect increased interest of the subjects since they were aware that the testing was coming to an end.

The inability to detect significant detrimental effects of mask wear on cognitive performance in this study does not prove that they do not exist, but suggests that other factors in the experimental design may have hindered the observation of such changes. The length of the testing period for continuous mask wear may not have been long enough to elicit changes in cognition. This factor may have also limited the findings of others (4,10,22,25,26). Secondly, our subject population was relatively stable in terms of anxiety proneness as measured by their trait anxiety levels. Morgan and Raven (20) were able to predict respiratory distress during respirator wear combined with heavy exercise from pre-test measures of trait anxiety. It is possible that if some of the subjects in our study had been more inclined to large increases in state anxiety (i.e. had "high" trait anxiety scores), more detrimental effects of respirator wear on reaction time may have been observed.

The findings of the current investigation also established that 10 hours of continuous mask wear did not significantly alter signal detection. Independent of time of measurement, assessment of the distribution of impairment to performance produced by mask wear within the visual field as measured with the use of the signal detection perimeter showed that the most peripherally and inferiorly placed stimuli were the most affected during mask wear. Peripheral stimulus rings (12° , 38° , 64° and 90°) showed that mean response times for signal detection increased with greater peripheralization for both test conditions. This general configuration of the data is comparable with the findings of previous research using this task (2,12-14). Impairments in signal detection time were significantly greater during mask wear compared to control at stimulus locations of 38° , 64° and 90° . As reflected by the reaction time literature, the 1-2 s impairments of signal detection time observed in this study are considered to be quite large and of practical significance (14).

Compared to the control test condition, M40 wear resulted in significantly longer response times at all field axis positions above and below the horizontal axis of the perimeter. These findings reflect the narrowing of visual field caused by M40 mask wear (5). As in previous research using the signal detection task, the least impairment in response time occurred along the horizontal axis of view, indicating that normal viewing during mask wear is most effective along the horizontal line of sight where most visual activity normally occurs (5,14).

The overall gender effect on cognitive performance showed that females exhibited significantly faster response times and decision making times for several CALCAP tasks. However, the gender effect was opposite for signal detection where males had faster average detection times than females. Gender difference literature related to psychology and cognition suggests that a difference would exist between response times for the cognitive performance tasks and the signal detection test (17,18). Since men tend to be better at spatial relationships than women, the signal detection task would most likely favor males. In contrast, the advantage of being better at remembering details within a cluttered background predisposes women to better performance to particular tasks of the CALCAP test battery.

5. CONCLUSION

Continuous wear of the M40 respirator for 10 hours in the absence of other stressors had no detrimental effects on cognitive performance, as measured by simple and choice reaction time. Signal detection time increased in direct relation to the peripheral location of the stimulus and best performance occurred for light signals located nearest the horizontal axis of view. The impairments in signal detection response time were significant during wear of the M40 mask compared to control conditions. However, signal detection did not change over the 10 hour wear period.

The implications of the results of this study for military performance suggest that respirator wear over relatively long time period in the absence of other stressors should not inhibit cognitive function or signal detection capability. Further studies need to be conducted to determine whether cognitive function is significantly altered during varying periods of continuous respirator wear while different levels of work tasks, representing the broadest spectrum of simulated wear conditions, are performed.

LITERATURE CITED

1. Brooks, F.R., and D.G. Ebner (1983). Psychological reactions during chemical warfare training. *Milit. Med.* 148:232-235.
2. Caretti, D.M. "Signal Detection Over the Visual Field During Wear of Various Respirators and Respirator Configurations." Technical Report, U.S. Army Edgewood Research, Development and Engineering Center, APG, MD. (In Print).
3. Caretti, D.M., W.D. Kuhlmann, and P.V. Pullen. "Determination of Mask Effective Dead Space Volume from Two Different Methods of Computation." Technical Report No. ERDEC-TR-154, U.S. Army Edgewood Research, Development and Engineering Center, APG, MD, 1994.
4. Caretti, D.M., L.A. Bay-Hansen, and W.D. Kuhlmann. "Cognitive Performance During Respirator Wear in the Absence of Other Stressors." *Am. Ind. Hyg. Assoc. J.* (In Print).
5. Caretti, D.M., and L.A. Bay-Hansen. "Respirator Wear and Exercise: Effects on Visual Acuity, Depth Perception, and Field of View." Technical Report, U.S. Army Edgewood Research, Development and Engineering Center, APG, MD. (In Print).
6. Carter, B.J., and M. Cammermeyer (1985). Biopsychological responses of medical unit personnel wearing chemical defense ensemble in a simulated chemical warfare environment. *Milit. Med.* 150:239-248.
7. Fine, B.J., and J.L. Kobrick. Assessment of the Effects of Heat and NBC Protective Clothing on Performance of Critical Military Tasks. USARIEM Technical Report No. T11-85, U.S. Army Research Institute of Environmental Medicine, Natick, MA, 1985.
8. Hamilton, B.E., and L. Zapata (1983). Psychological measurements during wear of the U.S. aircrew chemical defense ensemble. Technical Report No. 83-7, U.S. Army Aeromedical Research Laboratory, Fort Rucker, AL.
9. Johnson, A.T., R.A. Weiss, and C. Grove (1992). Respirator performance rating table for mask design. *Am. Ind. Hyg. Assoc. J.* 53:193-202.
10. Kelly, T.L., D.H. Ryman, A.A. Sucec, J.E. Yeager, C.E. Englund and D.A. Smith. The Effects of the M17A2 Gas Mask on Reaction Times and Accuracy in Males and Females Under Non-Exercising Conditions. NHRC Report No. 88-5, Naval Health Research Center, San Diego, CA, 1983.

11. Kelly, T.L., C.E. Englund, D.H. Ryman, J.E. Yeager, and A.A. Sucec (1988). The effects of 12 hours of MOPP IV gear on cognitive performance under non-exercise conditions. Technical Report No. 88-6, Naval Health Research Center, San Diego, CA.
12. Kobrick, J.L. "Effects of Hypoxia on Peripheral Visual Response to Rapid Sustained Stimulation." *J. Appl. Physiol.* 37: 75-79, 1974.
13. Kobrick, J.L., and E.R. Dusek. "Effects of Hypoxia on Voluntary Response Time to Peripherally Located Visual Stimuli." *J. Appl. Physiol.* 29: 444-448, 1970.
14. Kobrick, J.L., and L. Sleeper. Effect of Wearing Chemical Protective Clothing in the Heat on Signal Detection Over the Visual Field. *Aviat. Space Environ. Med.* 57:144-148 (1986).
15. Kobrick, J.L., A.R. Lussier, S. Mullen, and C. Witt (1987). A computerized system for measuring detection sensitivity over the visual field. *Aviat. Space Environ. Med.* 58:817-819.
16. Leibowitz, H.W. "Visual Perception and Stress." Paper presented at the First International Symposium on Physical Work and Effort, Stockholm, Sweden, December 1975, pp. 25-37.
17. Lips, H.M., A. Myers, and N.L. Colwill. "Sex Differences in Ability: Do Men and Women Have Different Strengths and Weaknesses?" in *The Psychology of Sex Differences*, ed. by H.M. Lips and N.L. Colwill, Englewood Cliffs, NJ: Prentice-Hall, 1978, pp. 145-171.
18. McGuinness, D. "Sex Differences in the Organization of Perception and Cognition" in *Exploring Sex Differences*, ed. by B. Lloyd and J. Archer, New York, NY: Academic Press, 1976, pp. 123-156.
19. Miller, E.N., P. Satz and B. Visscher. Computerized and Conventional Neuropsychological Assessment of HIV-1-Infected Homosexual Men. *Neurology.* 41:1608-1616 (1991).
20. Morgan, W.P., and P.B. Raven. Prediction of Distress for Individuals Wearing Industrial Respirators. *Am. Ind. Hyg. Assoc. J.* 46:363-368 (1985).
21. Rauch, T.M., C. Witt and L. Banderet. The Effects of Wearing Chemical Protective Clothing on Cognitive Problem Solving. USARIEM Technical Report No. T18-86, U.S. Army Research Institute of Environmental Medicine, Natick, MA, 1986.

22. Ryman, D.H., T.L. Kelly, C.E. Englund, P. Naitoh, and M. Sinclair (1988). Psychological and physiological effects of wearing a gas mask or protective suit under non exercising conditions. Technical Report No. 88-11 Naval Health Research Center, San Diego, CA.
23. Shershow, J.C., A. King and S. Robinson. Carbon Dioxide Sensitivity and Personality. *Psychosom. Med.* 35:155-160 (1973).
24. Spielberger, C.D., R.L. Gorsuch and R.E. Lushene. *The State-Trait Anxiety Inventory*, Palo Alto, CA, Consulting Psychologist Press, 1983.
25. Wetherell, A (1989). Effects of wearing the S6 respirator for 6 hours on the cognitive and psychomotor performance of male and female subjects (U). Technical Note No. 989, Chemical Defense Establishment, Porton Down Salisbury Wilts, UK.
26. Zimmerman, N.J., C. Eberts, G. Salvendy, and G. McCabe. "Effects of Respirators on Performance of Physical, Psychomotor, and cognitive tasks." *Ergonomics*. 34: 321-334, 1991.